II

RESEARCH ARTICLES

MODELING GRAYWATER IN RESIDENCES: USING SHOWER EFFLUENT IN THE TOILET RESERVOIR

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ABSTRACT

Use of municipal water in residences can be decreased substantially by allowing "graywater" effluent from showering and other activities to fill the toilet reservoir. This paper considers a system developed in Germany for treatment and storage of shower wastewater for use in flushing the toilet. Based on literature data for distributions of shower duration and water flow rate, the volume of municipal water saved using the German system has been estimated for several usage scenarios. Results show significant savings of water that depend on the size of the treatment and storage tanks used in the graywater system as well as the number of toilet flushes per day. For example, a scenario with four residents each flushing nine times per day with 80 liter treatment and storage tanks shows a 50% chance that the savings in municipal water use for the toilet will exceed 73%. Because the timing of showers and toilet flushes is assumed to follow a uniform distribution throughout the day, the calculated tank sizes may be underestimates.

KEYWORDS

graywater, indoor water use, water modeling, shower, toilet

INTRODUCTION

Approximately 4.68 billion m^3 of freshwater are used each year in residences in the U.S. (U.S. Geological Survey, 2006). Of this figure about 30% is used for hygiene and personal care (Hiller, 2003), while the rest is used for drinking, cooking, washing clothes and dishes, gardening, and other daily activities.

Although the importance of conserving water is well known in arid parts of the U.S., using water efficiently is becoming important throughout the country. This is because the treatment of potable water and the treatment of sewage cause environmental impacts from pollutant discharges and consumption of resources. A particular problem occurs during heavy rainfall, when the volume of sewage is suddenly expanded and the capacity of the wastewater treatment plant is exceeded. The result is serious: a large amount of untreated wastewater may flow into rivers, lakes and other bodies of water, causing damage to aquatic ecosystems (National Research Council, 2005). Reduction in the use of municipal water and in the outflow of sewage helps to reduce these impacts. Furthermore, the nation's water management infrastructure such as distribution networks, sewer lines, and treatment of both drinking water and sewage has deteriorated significantly from lack of funding (U.S. Environmental Protection Agency, 2002a). Adopting a more sustainable water management plan as part of rebuilding our infrastructure could greatly alleviate problems in the future.

How can we reduce freshwater use in residences? Vickers (2001) suggests ways to reduce residential water consumption by improving efficiencies of water use. Another way is to reuse wastewater generated in the house, after treating it. In this case, less external water from the municipal supply is needed, and less wastewater is drained to the outside. One way to do this is to use the effluent from the laundry and shower or bath, or other personal hygiene, to flush the toilets and water the yard. The residential wastewater from the laundry, shower, bath, or other uses is referred to as "graywater" (Green Builder, 2006; Little, 2006).

Large scale reuse of graywater in the U.S. has been studied by Asona (1998), who considered golf

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courses irrigated with treated municipal effluent and the use of effluent for ground water recharge. March et al. (2004) studied graywater reuse in hotel green practices. Surendran and Wheatley (1998) examined reuse of graywater in university dormitories.

In some areas of the U.S., graywater has already been used in residences. According to a survey by Water CASA (2006a), roughly 8% of the respondents in a southern Arizona survey in 1998 indicated that they reuse some of their graywater. The most frequently tapped source of graywater is clothes washers, accounting for 66% of all graywater sources; next are bathroom tubs/showers (15%) and kitchen sinks (10%). Bathroom sinks account for only 5%, and other graywater sources account for the remaining 4% (Water CASA, 2006a).

One of the key parameters in a graywater system is the size of the storage tanks and the length of time of storage of the graywater. Ludwig (2006) discusses ways to make rough estimates of the sizes of graywater tanks based on availability of residential wastewater and needs of the output graywater. However, a more rigorous consideration of graywater tank sizes is possible for specific systems. Such a consideration could save costs and space for oversized tanks or conversely prevent the use of more municipal water than is necessary.

In this paper, we consider effluent from the shower for flushing the toilet. According to Mitchell et al. (1999), the toilet accounts for around 29% of total indoor water consumption. The water used for showering/bathing, dishwashing, and doing laundry accounts for around 36%, 14% and 21% of the total indoor water consumption, respectively. Therefore, the volume of water used for showering is usually more than sufficient for flushing the toilet.

Based on an existing graywater system for flushing the toilet, we develop a stochastic model to examine how much municipal water can be saved for various water use scenarios. A Monte Carlo simulation is employed with the model to estimate the amounts of water used for showering and for flushing the toilet. Because virtually all the water used for the shower ultimately goes into the sewer system, the load on the sewage treatment plant is also reduced by the volume of municipal water saved.

It is recognized that the use of graywater has many potential problems. For example, contaminants in the water may clog pipes and degrade toilet components. One might surmise possible solutions: the wastewater could undergo some treatment to remove the most problematic contaminants, or valves could be used to allow only the final rinsewater from domestic bathing and washing to be used in toilets to minimize potential damage. The German water treatment system considered here has accounted for these problems in its design. However, in general, experiments are needed to determine what types of graywater would be usable in residential water pipes and toilets without causing damage. Such work is outside the scope of the current paper, which focuses only on the quantities of shower wastewater available and amounts of graywater needed for the toilet in a typical household.

BUILDING CODES FOR GRAYWATER

The legal definitions of graywater vary from state to state, with some states including only water from the laundry, baths, showers, and bathroom sinks in the definition. Other states include these sources as well as wastewater from the kitchen sink and dishwasher. For example, Minnesota defines graywater as "sewage that does not contain toilet sewage" (State of Minnesota, 2006). A summary of definitions is shown in Table 1.

Casanova (2001) points out that water from the kitchen sink and dishwasher often carries microbial organisms that may pose health risks. For this reason, Roesner et al. (2006) suggest that these types of wastewater should be considered "blackwater," with their flow going to the sanitary sewer rather than to a graywater collection system.

Many states in the U.S. have regulations and guidelines for graywater use. In most states that allow the collection and use of graywater, the collection system needs to be approved by the state authority before installation, and a septic tank is required. Some states allow graywater use only for surface irrigation, such as Arizona, while others allow its use only for subsurface irrigation, such as California, Nevada and New York.

Arizona, California, Florida, Georgia, Kentucky, Utah, and Washington have more comprehensive graywater regulations or guidelines. Usually these specify the type of graywater, septic tank size, surface soil absorption area and soil type, and graywater quality tests required. For example, Kentucky re-

TABLE 1. Major types of wastewater that are considered graywater, for states that have established legal definitions (some interpretation of terms in legal definitions have been applied).

State	Showers, Baths, Bathroom Sink	Kitchen Sink, Dishwasher	Washing Machine for Laundry
Alabama	+	+	+
		Garbage disposal excluded	
Alaska	+	+	+
Arizona	+	+	+
		Kitchen sink excluded	
California	+		+
Colorado	+	+	+
Connecticut	+	+	+
Florida	+		+
Georgia	+		+
Hawaii	+	+	+
Idaho	+		+
			Laundry water from soiled diapers excluded
Kentucky	+	+	+
		Garbage disposal excluded	
Maine	+	+	+
		Discharges from water closets excluded	
Maryland	+		+
Massachusetts	+	+	+
		Drains equipped with garbage grinders excluded	
Michigan	+	+	+
Minnesota	+	+	+
Missouri	+		+
Nebraska	+		+
Nevada	+		+
New Jersey	+		+
New Mexico	+		+
New York	+	+	+
Oregon	+	+	+
Rhode Island	+	+	+
		Discharges from water closets excluded	
South Dakota	+	+	+
Texas	+		+
Utah	+		+
Washington	+	+	+

Data source: US State Regulations (2006) http://weblife.org/humanure/appendix3.html#ny.

quires laundry water to be separated from the main house sewer; the laundry water is required to discharge into a lateral bed or trench(es) with a minimum of 100 square feet of bottom surface soil absorption area for a two-bedroom residence, and an additional 50 square feet for each additional bedroom (Kentucky Cabinet for Human Resources, 1989). In addition to the minimum graywater trench drainfield absorption area, Florida also sets the minimum capacity of the graywater retention tank (Florida Department of Health, 1998).

Some states have only general graywater usage requirements. For example, Pennsylvania mentions that liquid wastes, including kitchen and laundry wastes and water softener backwash, are required to be discharged to a treatment tank (Pennsylvania Department of Environmental Protection, 1998). Other states, such as Alaska, Missouri, and Nebraska give definitions of graywater without any regulations. Still other states, such as Maryland and Idaho, allow graywater systems to be installed for experiments or on a case-by-case basis.

A search through regulation documents pertinent to this field suggests that the following states have no graywater regulations: Alaska, Arkansas, Delaware, Illinois, Indiana, Iowa, Kansas, Louisiana, Mississippi, Missouri, Montana, Nebraska, New Hampshire, North Carolina, North Dakota, Ohio, Oklahoma, South Carolina, Tennessee, Vermont, Virginia, West Virginia, Wisconsin and Wyoming (US State Regulations, 2006).

USE OF GRAYWATER FOR FLUSHING THE TOILET

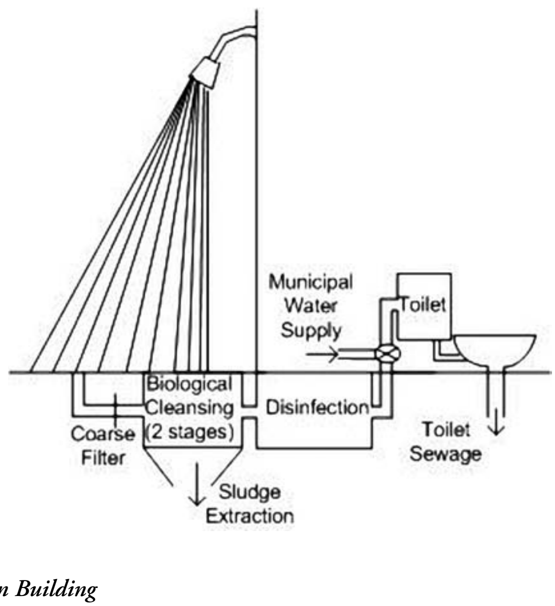
There are no specific regulations regarding use of graywater in toilets. Water CASA (2006b) gives general requirements for using graywater in residences. For example, graywater cannot be used outside the owner's private residence, and graywater storage tanks must be covered to restrict access and to eliminate habitat for mosquitoes and other vectors. In some cases, graywater use for irrigation is permitted.

Considering that the required water quality for flushing the toilet is not likely to be more stringent than the water quality for irrigation, it is feasible to consider using graywater collected from personal hygiene in the bathroom after treatment, which would satisfy irrigation requirements, to flush the toilet.

According to the German Federal Environmental Agency (Umwel Bundes Amt or UBA, 2006), approximately 60 liters of graywater are generated per person daily in a water conserving household, independent of weather. UBA has proposed a system for using treated shower effluent to flush the toilet, as illustrated in Figure 1. There are 3 processes in the treatment system. First, the shower water flows through a coarse filter. Second, biocultures are used to break down contaminants into waste sludge which is then removed from the water and fed into the sewer line. Finally, ultraviolet treatment disinfects the water. The treated wastewater then flows into a storage tank. The full process takes roughly four hours, nearly all due to the second step. Note that municipal water automatically flows to the toilet in the event there is insufficient treated wastewater for one toilet flush. According to UBA (2006), the quality of treated water meets the EU guidelines for bathing water. With this system, the payback period is expected to be seven years.

While the system is designed in Germany, the benefits of utilizing such a system in a household in the US have not been studied quantitatively. In this paper, we describe such a study based on probabilistic analyses of various water usage scenarios.

FIGURE 1. A German graywater treatment system. Redrawn from UBA (2006).



PROBABILISTIC ANALYSIS

To be able to perform any kind of analyses on the German-based system, one needs to model the associated graywater treatment process and generate a number of water use scenarios. The sections below describe such modeling efforts.

Modeling the Graywater Treatment Process

We assume there are two tanks of the same size. Effluent from the shower, with coarse particles removed, flows into Tank 1 and receives 4 hours of biological cleansing treatment. The water then flows into Tank 2 for disinfection and stays there until needed to flush the toilet. The time for disinfection can be neglected.

There is a valve between Tank 1 and Tank 2 that needs to remain closed during the biological cleansing treatment. Hence, the graywater treatment process is modeled as follows:

- When the treatment of water in Tank 1 is completed, this water will flow into Tank 2 until it is filled or Tank 1 has been emptied.
- When Tank 2 is full, the treated wastewater remains in Tank 1 even after treatment is finished.
- If the toilet is used when Tank 2 has insufficient water for one flush, municipal water is used in the toilet.
- If there is a shower and Tank 1 is full, all of the shower water becomes sewage.
- If a shower occurs when there is less than a full tank of treated wastewater left in Tank 1, the fresh shower effluent still flows into Tank 1 and mixes with the effluent treated previously. The resulting mixture then needs to go through 4 hours of treatment, after which time the valve between the tanks opens. The newly treated wastewater is then available to flow into Tank 2 when there is space in that tank.
- If there is insufficient water in Tank 2 for a toilet flush and the Tank 1 treatment finishes at the same time as a toilet flush, municipal water is used for the flush. After the flush, the newly treated water will flow into Tank 2 to be used for the next flush.

Modeling Water Use Scenarios

Water Use Scenarios. In generating and analyzing the water use scenarios, we determine the number of residents in the house as being 2, 3 or 4 and assume each resident takes 1 shower per day. We also set a frequency of flushing the toilet for each resident, ranging from 5 to 9 flushes per day. This range for frequency of flushes is based on Mayer et al. (1999) who report that a toilet in a residential dwelling is typically flushed 5-6 times per person per day. The combination of number of residents and number of flushes per person per day defines a scenario. For example, in one scenario there are three residents and each flushes the toilet six times per day, so there are three showers providing graywater for eighteen toilet flushes each day. As a result of such combinations, we have fifteen scenarios to analyze.

Timing Selection for Shower or Use of the Toilet. We assume that all residents use a single bathroom, and all water use activities occur between 6 am and 1 am the next morning. This timeframe is divided into minutes and each minute is regarded as a time slot, resulting in 1,140 time slots on a given day. Each slot is occupied by a shower, by use of the toilet, or is empty. The timing for use of the shower and use of the toilet is assumed to occur with equal probability for all time slots, i.e., the timing for showers and flushes is selected randomly from a uniform distribution. This timing has been adopted for simplicity to illustrate the method, since water use in residences is only now becoming more widely studied and data for the timing of personal showers is not freely available. To obtain better information, further surveys of residential populations regarding their water use would be needed. Thus the water tank sizes calculated here must be regarded as lower limits. For example, if all showers in a household were taken in the morning, replenishment of the graywater tank with shower wastewater during the morning would have to supply water for toilet flushes throughout the rest of the day.

Water Consumption and Duration of a Shower. Data on water use and shower duration are randomly selected based on a lognormal distribution. Wilkes et al. (2005) have studied water use for showers by Americans using databases of the National Human Activities Pattern Survey (NHAPS) and the Residential End Uses of Water Study (REUWS). Their results show that the duration and water flow rate of a shower are both log-normal distributions. For shower duration, the geometric mean μ_g is 11.3 minutes and the geometric standard deviation σ_g is 1.58. For the water flow rate, μ_g is 7.5 liters/minute and σ_g is 1.46. The data used for our simulations are based on these known distributions.

In addition, James and Knuiman (1987) have studied indoor water use for over 2,000 households in Perth, Australia. Their study also shows that the distributions of duration and water flow rate of a shower are log-normal. According to their study, the geometric mean shower duration is 6.8 minutes and the geometric standard deviation is 1.74, while the geometric mean water flow rate is 7.1 liters per minute and the geometric standard deviation is 1.45. Here we use the data from Wilkes et al. (2005) because they are up-to-date and based on the U.S.

Water Consumption and Duration of a Toilet Flush According to the U.S Energy Policy Act (1992), Standards for Water Closets and Urinals, the maximum water use for "gravity tank-type toilets," "flushometer tank toilets," and "electromechanical hydraulic toilets" is 1.6 gallons (6.1 liters) per flush. We assume here that the volume of water used per flush is fixed at 6 liters.

We also assume for simplicity that the duration of each toilet use is one minute, although the results are not sensitive to this assumption. Thus each use of the toilet occupies one minute, while the time occupied by a shower is a random number selected from a log-normal distribution.

Figure 2 shows an example of the time slots occupied by shower and toilet use for the scenario above, where there are three residents and each flushes the toilet six times per day. The three showers occur at 11:46am, 5:31pm and 10:05pm, and the water flow rates are 4, 8 and 5 liters per minute, respectively. The first flush of the toilet occurs at 7:32am and the last one occurs at 11:35pm.

Modeling Both Water Treatment and Use

A C program has been implemented to simulate water use by the graywater system in Figure 1. Monte Carlo simulations have been used for these calculations. This type of simulation is useful when a mathematical model cannot be solved analytically. The method relies on a computer to generate "random" distributions of values for simulated model input data. Although a computer is deterministic and cannot generate truly random distributions, algorithms have been developed to generate pseudo-random distributions that can satisfy the demands of the Monte Carlo method. The distributions can be chosen based on observations of a real system, whether this is a uniform distribution, a bell-shaped curve, or a more complex function. The random values are used as inputs to the model to produce output; this numerical experiment is repeated a large number of times, and the distribution of outputs represents the solution set. In this study, the simplest case of a uniform distribution has been used to illustrate the method.

The simulation period in our study is 20,000 days. We assume Tanks 1 and 2 are initially empty. Since there is no water use activity between 1 am and 6 am, and the water treatment time is 4 hours, any

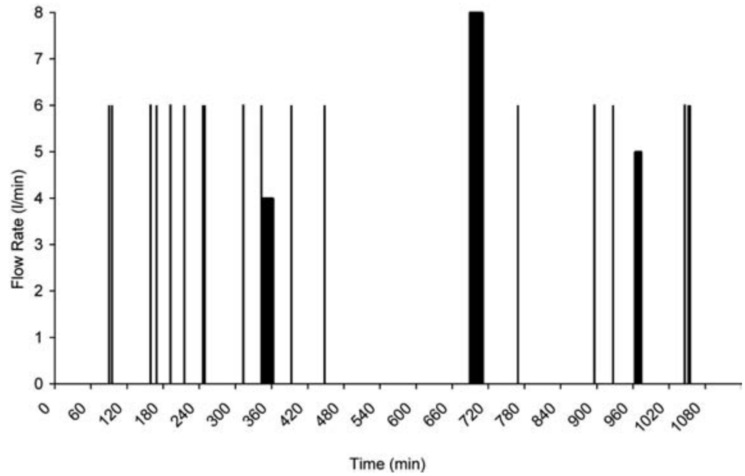


FIGURE 2. Distribution of showers and toilet flushes during a day.

shower effluent remaining in Tank 1 at the end of a day is assumed to be fully treated by the beginning of the next day.

The simulation has been run for several possible sizes of Tanks 1 and 2, which are both assumed to have the same volume. Results are shown in Figures 3, 4, and 5 for nine different scenarios.

Figure 3 shows that two 40-liter tanks in a residence with two persons, five flushes each per day, provides a 70% probability that no municipal water will be needed for any of the toilet flushes in a day. The probability is 82% that less than 10 liters of municipal water will be needed to flush the toilet; there is a 91% chance that less than 20 liters of municipal water will be needed. If the size of each tank is increased to 50 liters, the chance of needing no municipal water increases from 70% to 91%. For tank sizes greater the 50 liters, the probability approaches 100%.

If each resident flushes the toilet seven times per day, the probability of avoiding municipal water use decreases substantially compared with five flushes. For example, the probability that less than 10 liters of municipal water is needed decreases from 82% to 38%. If each resident flushes the toilet nine times per day, the probability drops to 7% according to Figure 3.

Similarly, Figure 4 shows the results if there are three residents, each of whom flushes the toilet 5, 7, or 9 times per day. Although more shower effluent is

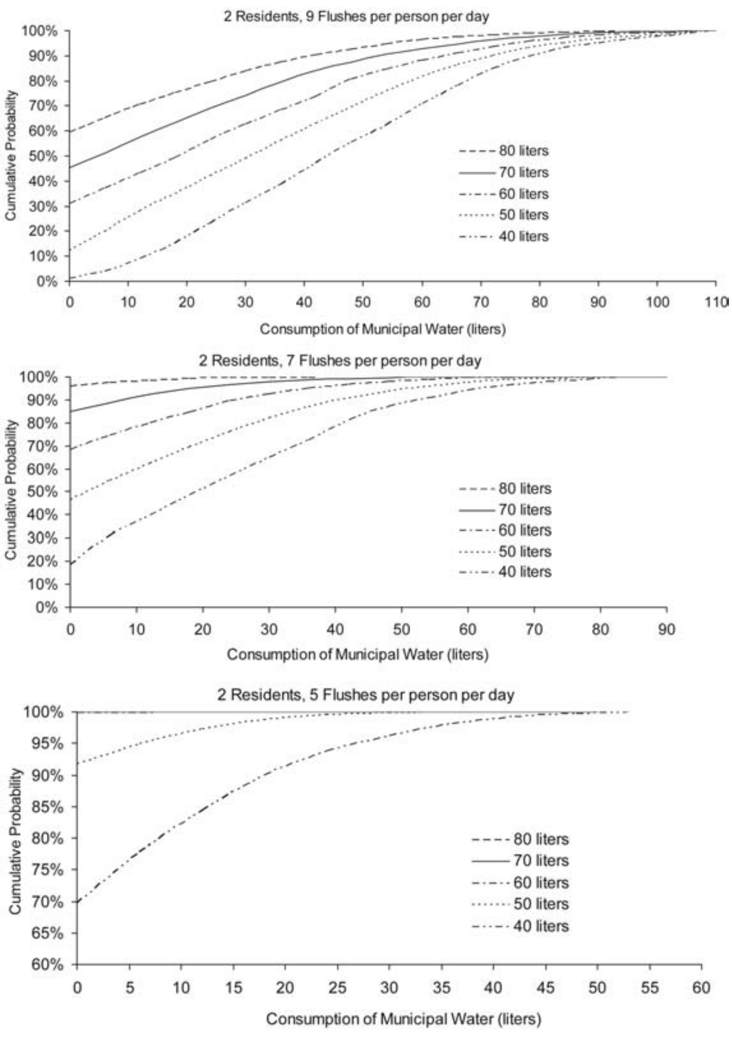


FIGURE 3. Cumulative probability for the volume of municipal water consumed when the graywater system in Figure 1 is equipped with two tanks of the indicated size. There are 2 residents, each of whom flushes the toilet 5, 7 or 9 times per day.

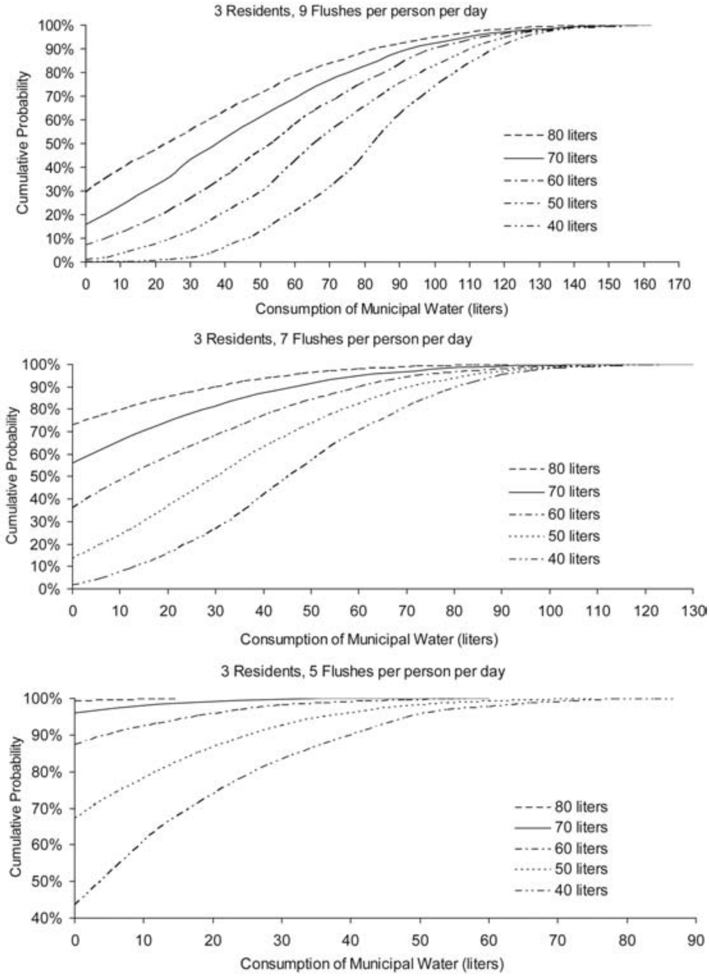


FIGURE 4. Cumulative probability for the volume of municipal water consumed when the graywater system in Figure 1 is equipped with two tanks of the indicated size. There are 3 residents, each of whom flushes the toilet 5, 7 or 9 times per day.

generated compared to two residents, the probability of needing municipal water increases because of greater toilet use with only small tanks to store shower effluent. As tank size increases, the benefits of more shower effluent become significant.

Finally, Figure 5 shows the results if there are four residents. The probabilities of needing municipal water continue to increase compared with water use by three residents. For the largest tank size, however, the benefits of significant shower effluent increase in importance as in Figure 4.

Another way to graph the data is to consider the percentage of municipal water *saved* for each scenario. If there are four residents and each flushes the toilet nine times per day, the 36 flushes daily will require 220 liters of water. Figure 6 shows that there is a 50-50 chance that at least 73% of this water will be saved using the graywater system with two 80-liter tanks.

Although the Monte Carlo simulation has been used here only to estimate the sizes of graywater tanks for one specific system, such simulations could be valuable for other graywater systems or even for water use components in general. For example, sizing hot water tanks and washing machines could benefit from this method by reducing water and energy demand to match actual use patterns. Further research in personal water use would be needed to make maximum use of the method.

CONCLUSIONS

The German graywater system considered can provide reductions in the use of municipal water for

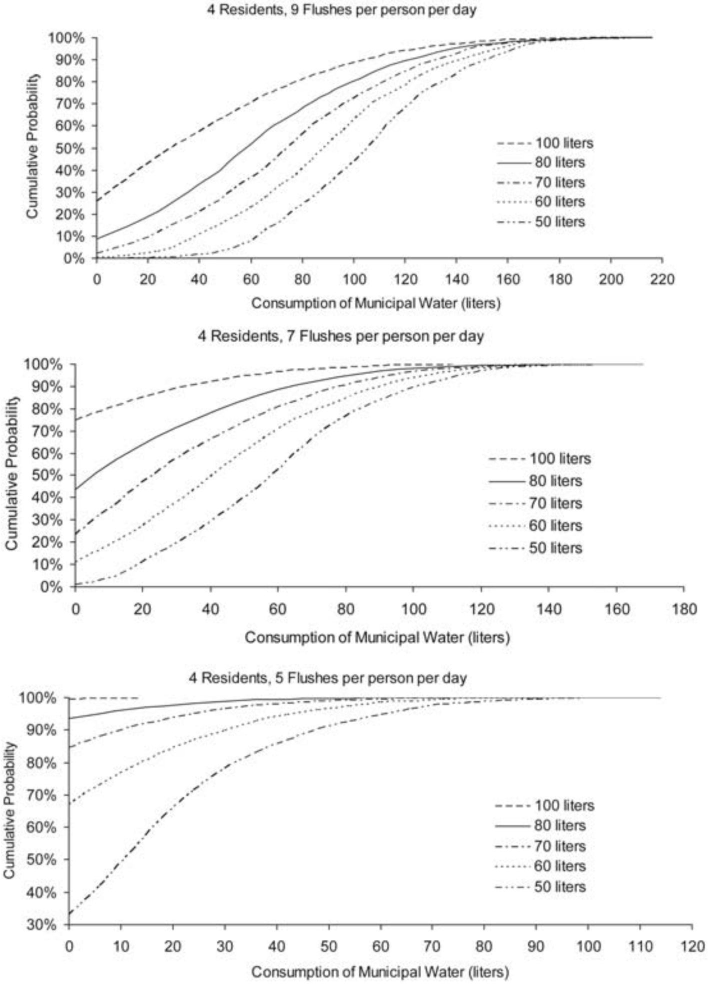


FIGURE 5. Cumulative probability for the volume of municipal water consumed when the graywater system in Figure 1 is equipped with two tanks of the indicated size. There are 4 residents, each of whom flushes the toilet 5, 7 or 9 times per day.

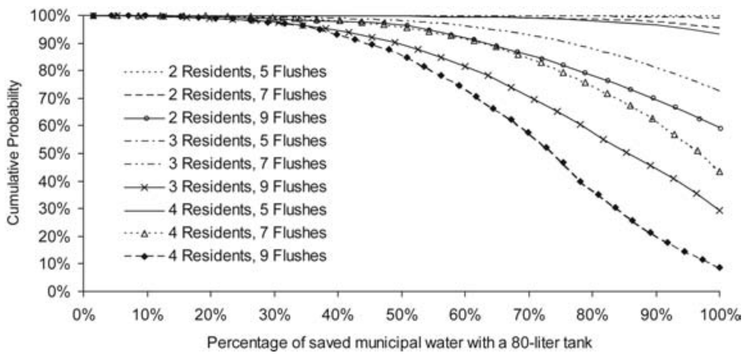


FIGURE 6. Percentage of municipal water saved when the graywater system of Figure 1 is equipped with two 80-liter tanks.

flushing the toilet. For typical shower lengths and water flow rates, the effluent from the shower can be treated over a four-hour period and then stored until needed for the toilet. With two residents who shower daily and flush the toilet less than ten times per day, there is a near 100% probability that no municipal water will be needed to flush the toilet as long as the graywater system uses an 80 liter tank for treatment and another 80 liter tank for water storage. Varying amounts of municipal water for flushing the toilet will be needed if there are more than two residents; reducing the municipal water use in this case will require larger tank sizes. Future studies should include an economic cost-benefit assessment of such a system based on tank sizes determined through simulations, e.g., like those described here.

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REFERENCES

Asano, T. (1998). "Wastewater Reclamation, Recycling, and Reuse: An Introduction." In: *Wastewater Reclamation and Reuse.* Takashi Asano, (ed), Technomic Publishing, Lancaster, Pennsylvania, p. 40.

Casanova L.M., V. Little, R. J. Frye, and C.P. Gerba (2001). "A Survey of the Microbial Quality of Recycled Household Graywater." *Journal of the American Water Resources Association.* 37(5): 1313–1319.

Florida Department of Health (1998). Chapter 64E-6, Florida Administrative Code, Standards for On-Site Sewage Treatment and Disposal Systems. p. 31.

Green Builder (2006). Graywater <http://www.greenbuilder.com/sourcebook/Greywater.html> (August 26, 2006).

Hiller, C. (2003). "Sustainable energy use in houses: Will the energy use increase with time?" *Study of Literature and Computer Estimations*. Report TVBH-3041 Lund 2003, Department of Building Physics, SP Swedish National Testing and Research Institute, Boras, Sweden.

James, I.R., and M.W. Knuiman (1987). "An application of Bayes Methodology to the analysis of diary records from a water use study," *Journal of the American Statistical Association*, 832(399): 705– 711.

Kentucky Cabinet for Human Resources (1989). On-Site Sewage Disposal Systems Regulations. 902 KAR 10:081 and 902 KAR 10:085. pp. 58–59.

Little, V. (2006). Graywater Guidelines. The Water Conservation Alliance of South Arizona Presents <http://www.watercasa.org/> (August 10, 2006).

Ludwig, A. (2006). *Builder's Greywater Guide: Installation of Greywater Systems in New Construction and Remodeling,14th edition*, Oasis Design, Santa Barbara, CA.

March, J.G., M. Gual, and F. Orozco (2004). "Experiences on Greywater Re-Use for Toilet Flushing in a Hotel (Mallore Island, Spain)," *Desalination,* 164:241–247.

Mayer, P.W., W.B. DeOreo, E.M. Opitz, J.C. Kiefer, W.Y. Davis, B. Dziegielewski, and J.O. Nelson (1999). *Residential End Uses of Water*. Report to AWWA Research Foundation and American Water Works Association (AWWA), Denver, CO.

Mitchell, G., R. Mein, and T. McMahon (1999). *The Reuse Potential of Urban Stormwater and Wastewater*. Industry Report. Report 99/14, Dec., 1999.

National Research Council (2005). *Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania*, The National Academies Press, Washington, DC.

Pennsylvania Department of Environmental Protection (1998). Pennsylvania Code. Title 25. Environmental Protection. pp. 73–10.

Roesner, L., Y. Qian, M. Criswell, M. Stromberger, and S. Klein. (2006). Long term effects of landscape irrigation using household graywater—literature review and synthesis (Final Report 03-CTS-18CO), Water Environment Research Foundation.

State of Minnesota (2006). Minnesota Rules, 7080.0020 Definitions. <http://www.revisor.leg.state.mn.us/arule/7080/0020.html>, last accessed on August 16, 2006.

Surendran, S., and A.D. Wheatley (1998). "Gray-water Reclamation for non-potable re-use." *Journal of the Chartered Institution of Water Environmental Management,* 12:409.

Umwel Bundes Amt or UBA (2006). German Federal Environmental Agency <www.umweltbundesamt.de> (August 16, 2006).

U.S. Energy Policy Act (1992). <https://energy.navy.mil/publications/law_US/92epact/hr776toc.htm>.

U.S. Environmental Protection Agency (2002). *The Clean Water and Drinking Water Infrastructure Gap Analysis*, September 2002.

U.S. Geological Survey (2006). *Water Resources of the United States*. <http://water.usgs.gov/watuse/pdf1995/pdf/summary.pdf> (May 24, 2006).

U.S. State Regulations (2006). US State Regulations of Composting Toilets, Graywater Systems, and Constructed Wetlands, <http://weblife.org/humanure/appendix3.html> (August 26, 2006).

Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amherst, MA: WaterFlow Press, 2001.

Water CASA (2006a). Residential Graywater Reuse: The Good, The Bad, The Healthy. <http://www.watercasa.org/resreuse.htm> (August 26, 2006).

Water CASA (2006b). Can I Use Graywater? <http://www.watercasa.org/brochure.htm> (August 16, 2006).

Wilkes, C.R., A.D. Mason, and S.C. Hern (2005). "Probability distributions for Showering and Bathing Water—Use Behavior for Various U.S. subpopulations." *Risk Analysis,* 25(2): 237–337.